DOCUMENT RESUME

ED 298 902 IR 013 287

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TITLE Programmed Instruction to Computer-Based Instruction: The Evolution of an Instructional Technology.
PUB DATE 84
NOTE 9p.; In: Instructional Development: The State of the Art, II; see IR 013 273. For volume I, see ED 292 444.
PUB TYPE Historical Materials (060) -- Information Analyses (070) -- Viewpoints (120)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Aptitude Treatment Interaction; *Behaviorism; *Cognitive Psychology; *Computer Assisted Instruction; Educational Technology; Feedback; *Programed Instruction; Psychological Studies; Task Analysis; *Teaching Machines
IDENTIFIERS Intelligent CAI Systems; *Pressey (Sidney Leavitt); *Skinner (B F)

ABSTRACT

This review of the evolution of programmed instruction from Pressey and Skinner to the present suggests that current computer technology will be able to free the learner from the limitations of time and place as Pressey originally proposed. It is noted that Skinner provided the necessary foundation for treating the learning process on an individual basis, while Pressey not only provided the necessary technological implement--the teaching machine--but also anticipated the present cognitive perspective and its importance for the instructional technology of the present and the future, i.e., the computer. It is suggested that programmed instruction, with its basis in cognitive psychology, is better able to handle complexity than other forms of instruction, and recent developments in aptitude-treatment interaction (ATI) research are discussed. Finally, the use of intelligent computer-assisted instruction is considered in the context of the SOPHIE (SOPHisticated Instructional Environment) system, and it is suggested that such systems represent the realization of the type of teaching machine first envisioned by Pressey. (EW)

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B. DESIGNS

Chapter 14

Programmed Instruction to Computer-Based Instruction: The Evolution of an Instructional Technology

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Can we, as Pressey originally proposed for programmed instruction, free the learner from the limitation of time and place?

This chapter explores the evolution of programmed instruction from the early Pressey/Skinner days to the present and proposes that present computer technology is capable of answering the above-stated question in the affirmative.

From the early 50s to the beginning 80s, there has been a progressive shift in the theoretical perspectives on the psychology of learning and instruction. This shift has been from the behavioral perspective to the cognitive perspective and has been matched by a corresponding shift in the research and implementation of instructional technology supporting individualized instruction.

In order to avoid the tendency to go all the way back to the venerable examples and techniques of the Greeks (Aristotle in particular), let us agree that the modern foundation of individualized instructional technology derives primarily from the work of two individuals--Sidney L. Pressey and B. F. Skinner. Pressey, of course, provided the teaching machine which clearly represents instructional technology as product. Skinner provided the form of behaviorism which served as the basis for the systematic control of the learning activity, which, in turn, is representative of instructional technology as process.

Though both Pressey and Skinner shared a strong empiricist orientation toward their respective work, their perceptions of the form and use of instructional technology, popularized as Programmed Instruction (PI), was markedly different. Skinner and the PI which followed his orientation provided the necessary foundation for treating the learning process on an individual basis and in a manner which was both prescriptive and specifiable. Pressey, in addition to providing the necessary technological implement, anticipated, as will be shown, the present cognitive perspective and its importance for the instructional technology of the present and the future--the computer.

Programmed Instruction has developed both as product and process, though of late it has generally been thought of in process terms.[1] As process, PI refers to the systematic development of instruction beginning with a needs analysis, or assessment, and a task analysis, both leading to the determination of instructional or behavioral objectives. This analysis of required learning performance and the production of objectives is followed by the development of appropriate criterion test items for assessing the specified objectives and their encompassed levels of performance. At this point, the primary goal of the PI process is to focus on required student performance--the desired observable behavior--and the elimination of "nice-to-know" peripheral information.

Subsequent to the analysis/specification stage of the PI process is the production/design stage. This stage involves the selection of appro-

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priate instructional strategies and media to achieve the instructional objectives. The production/design stage also involves the design of PI as product and includes decisions about the sequence, format, and content of the instruction delivered.

The final stage of the PI process is validation or evaluation. This is the empirical "proof-is-in-the-pudding" test of the worthiness of the instruction which has been designed. Perhaps this stage best represents the scientific/systematic demands of the PI process versus those of a philosophical /artistic approach to the development and delivery of instruction. For the PI process, instructional failure resides more in the instructional design than in either the teacher or the learner. The validation activities occur at two levels. At the first level, small group tryouts are conducted to provide formative information as to the adequacy of original design conceptions and to provide direction for revision. At the second level, large group tryouts and field implementation are conducted to provide summative information for determining the final adequacy of the instructional design and the sufficiency of the instructional analysis of stage 1.

The three stages described--analysis, production or design, and validation or evaluation--represent PI as process. Though there are several models for Instructional Systems Development (ISD), as the PI process has become known, each differing somewhat in the number of steps specified, they all are characterized by the three stages of activity just described.[2] These three stages also represent the activities of the basic scientific, empirical approach--hypothesis generation, experimental design, and hypothesis testing. This basic scientific or "systematic" approach has, of course, served scientific rational man quite well. However, the mystique of its use is that, in and of itself, it produces what one might call "instructional truth." This is an illusion, of course, in that the process is self-regulating so as to ensure original purpose. Purpose, however, lies outside of the regulatory mechanisms of the PI or ISD process and is best reflected by the product of that process--the act of instruction and its consequences.

The act of instruction, or how instruction is delivered, reflects perceptions of what the learner is. This perception, in turn, dictates the form of instruction. Skinnerian behaviorism perceives the learner as a reactive organism. For a given stimulus, the learner responds and is rewarded. The original and classic form of PI represented this view by presenting instruction in small "frames" as discrete stimuli. These frames are followed by the opportunity to make a written or constructed response which, in turn, is immediately followed by confirmation of the correctness of the response given. This classic form is reflected in the definition provided by Bullock[3] in Volume 14, Programmed Instruction, of Educational Technology Publication's The Instructional Design Library:

> Programmed instruction is described as instructional packages having certain key characteristics or features: self-pacing; frequent opportunities for overt responding to problems/questions (items) accompanied by immediate feedback; and a highly structures (pro grammed) sequence of self instructional units (known as "frames").

Programmed instruction as product became the technology which permitted concepts from behavioral learning theory to be applied. The behavioral laboratory showed that behavior is a consequence of a reinforcing event. Reward a behavior and it is strengthened. Non-reward leads to extinction of the behavior. The behavior laboratory also showed that behavior is shaped through the incremental and cumulative reinforcement of successive approximations to the desired end-behavior. Additionally, if reinforcement was to be successful, it had to be immediate. The group setting of traditional instruction provides an insufficient setting for the development of desired behaviors. Though one could present a desired behavior broken down into small incremental steps or stimuli, the capability to allow responding by all individuals with immediate reinforcement is certainly limited. A different instructional format was needed--one which dealt with behavior on an individual basis. The printed programmed text became the technology of choice for individual, behavioral-based instruction.

Skinner capitalized on the work Pressey did with the teaching machine, but he rejected its original application using multiple-choice type questions.[4] For Skinner, the teaching machine was a necessary instrument if one were to apply behavioral principles in instructional design.

> Human behavior is distinguished by the fact that it is affected by small consequences...We call an effective person "discriminating" ...contingencies of reinforcement are responsible for human discriminative behavior...The number of reinforcements required to build discriminative behavior in the population as a whole is far beyond the capacity of teachers. Too many teachers would be needed, and many contingencies are too subtle to be mediated by even the most skillful. Yet relatively simple machines will suffice.[5]

However, Pressey's teaching machine was inappropriate for programmed instruction because it didn't permit constructed responses and it permitted, through the use of multiple-choice items, erroneous responses. It did, though, provide a mechanism for individual instruction with the potential of unfailingly controlling response contingencies.

For many years, and even to the present, PI

both as product and process functioned to shape instruction as the identification of behavioral elements which would be linearly and progressively presented and reinforced. However, very early in the PI movement, differing conceptions of the nature of learning and the appropriate form of PI were put forth.

Pressey devised his teaching machine not as a mechanisn for the presentation of instruction, but rather as a device to engage the learner with the instructional material which had been previously presented. The teaching machine enabled the individual learner to assess her/his understanding of instructional content and, through the mechanism of immediate knowledge of results, to either confirm her/his correctness of understanding, or to correct her/his errors of understanding. For Pressey, learning was not an..."accumulation of responses governed by environmental contingencies"[6] but rather a process which involved instilling meaningful cognitive structure.[7]

Structure of content and the meaning inherent in it was an important consideration for Pressey. One of his major criticisms of Skinnerian-based, frame-oriented PI was that such a breakdown of a subject-matter into sequential elemental bits destroyed the structure which gives meaning to the material. Pressey suggested:

> that the initial presentation might often best be a very well-organized and well-written substantial statement much like a chapter in a good textbook! And the autoinstruction should follow and should be like a series of questions in a very good discussion of such a chapter.[8]

The concern of Pressey was for the interaction that a learner has with instructional content. For this reason, the use of multiple-choice questions rather than simple constructed responses was not something to be avoided. Instead, multiple-choice questions provided the means by which potential misunderstandings could be represented. An error made by the learner provided the mechanism for clarification through differentiation. This, in essence, represents a cybernetic view, which contends that feedback, or knowledge of results, is informative rather than reinforcing, and permits the learner to self-correct inappropriate knowledge or behavior toward the correct standard.

Subsequent research has, in fact, borne out the validity of Pressey's view regarding the form of response and the nature of feedback. This research has been reviewed by Kulhavy.[9] The results generally point to the fact that feedback provides correction of errors and helps the student to integrate new knowledge with prior knowledge; it does this by informing the student of the correctness of her/his response in relation to both specific and general information s/he already has. Perhaps most damaging to the original behavioristic view that feedback served as reinforcement was research which showed that delayed feedback in certain instances was better than immediate feedback. In fact, students spend more time studying feedback if it is delayed rather than if it is provided immediately after difficult material. The feedback serves to both identify errors and to allow their correction. Control of feedback is important, also, because it has been shown that feedback will not have a facilitative effect if the learner does not have to engage the material in order for her/him to receive the feedback. In such cases, easily-available feedback short-circuits the processing of information or instruction.

Feedback as information for correcting errors presumes that learners will make such errors. This conception immediately liberated the form of PI from its initial concern with small steps as a means to ensure correct responding which could be reinforced. The informative nature of feedback also implies that different learner errors should require differential corrective feedback. Provision of such differential feedback leads to nonlinear branching techniques such as in the form of Crowder's Intrinsic Programming.

Several things are important to the consideration of Crowder's Intrinsic Programming and the form of PI that required.[10] First, response-generating questions served a diagnostic purpose, assessing the learner's meaningful comprehension of the presented instructional content. Errors indicated the need for specific remedial information. Rather than proceeding through instruction in a linear fashion, intrinsic programming presented the student with multiple paths, which gave the appearance of randomly ordered "frames." To proceed, the learner had to make a response which then resulted in the next specifiable point in his path. This availability of different paths of instruction redefined the meaning of and the need for individual instruction: from the simple, proper provision of reinforcement to the diagnosis and adminsitration of instruction based upon the unique requirements of the individual and upon her/his individual performance. With intrinsic programming, PI moved toward the handling of the complexity of individual differences, but the technology of programmed texts and of electromechanical "teaching machines" proved to be a limiting factor to the instructional accommodation of such individual differences.

Printed programmed instructional materials have typically offered poor control over access to feedback. With much of the programmed material which was developed, it was not unusual to find learners not using their sliding masks to cover feedback information, but rather peeking at the answer at the end of the text or on the other page before responding. Control of feedback in printed materials came through a variety of gimmicky chemical or punchboard techniques. If intrinsic programming was pursued, any complex application of branching soon would leave the learner in a state of confusion or inconveniently flipping pages back and forth.

Electro-mechanical teaching machines improved the control of feedback and also provided

less obtrusive mechanisms for branching from one place in a lesson to another. But not even the most sophisticated of these devices was or is able to carry on a dialogue over time with a learner, or to modify the sequence or level of instruction, not simply on the basis of a single, immediate response, but on the basis of a history of responses.

COGNITIVE PSYCHOLOGY, INSTRUCTION, AND THE COMPUTER

As we have seen, programmed instruction developed first as product, the programmed text and the linear-sequenced teaching machine; it was developed in order to provide a mechanism by which principles of Skinnerian behaviorism could be applied to the learning process and to instruction. The activity of creating these products evolved into programmed instruction as process, to determine appropriate instructional stimulus conditions and their corresponding response requirements and to verify that the expected learning behavior was in fact being achieved. Individualization was a function of this technology because only at the level of the individual could reinforcement be properly administered. However, the teaching machine, which became intimately associated with the concept of programmed instruction, was originated by its inventor, Pressey, not as a device to accommodate the presentation of stimulus materials and reinforcement schedules, but as a device to accommodate individual differences. The Pressey teaching machine was a self-assessment device for helping students individually process instructional information, no matter how received. As we will soon see, the consideration of individual differences, and their accommodation by the instructional process, raises measurably the level of complexity which must be dealt with. The instructional technology required, both in terms of product and process, must be commensurate in its ability to handle the required complexity.

The concept of individual differences has had a long tradition in psychology, especially in the area of mental measurement and IQ testing. However, in instruction, the planned design of treatments to accommodate specific individual differences has had a more recent history, associated with research in the area of study known as Aptitude-Treatment-Interactions or ATI's. This work, most noteably associated with Lee J. Cronbach and Richard E. Snow, "has been aimed at discovering the differential effects that differing instructional treatments may have on students who vary on some measure of aptitude."[11] Thus, for example, "high verbal" students would be expected to do well with more visual and/or auditory materials, such as sound/slide presentations.

The original and continuing goal of many ATI research efforts is to establish a body of data which would permit a predictive classification system; this system would enable instructional designers to specify a particular and maximally beneficial form of instruction for a learner with particular aptitude levels. This goal, if developed to its fullest extent, has significant implications for instructional technology both as process and as product. It also raises the issue of whether or not the terminology and the existing concepts of programmed instruction are sufficient to encompass and deal with the nature of the instructional design requirements engendered by the consideration of individual differences within the framework of ATI research.

Consideration of newer instructional technologies should attend to the point that there has always been a unique interplay between science and technology. Isaac Asimov addressed this point in an article in the Saturday Review, wherein he took exception to elitist distinctions made between "pure" science and "applied" science and technology.[12] In this same article, Asimov points out that "The fact is that science and technology are one,"[12] and that the history of scientific successes is a history of its tools as well as of its ideas. New technology provides new avenues for scientific speculation and discovery. The psychology of learning, a "pure" science, and the psychology of instruction, an "applied" science, also interplay around the technology used. The advent of new technology presents new opportunities for both scientific and practical activities. In this context, the technology of programmed instruction has necessarily evolved to a level of technology which is more capable than in the past of dealing with the evolving complexities inherent in present conceptions of human learning activity. This new level of technology is most highly developed in Computer-Aided Instruction (CAI).

As mentioned earlier, the ATI approach to individual differences raises the level of complexity of instruction. In terms of the first stage of the original PI process, analysis now requires assessment not only of the task requirements as dictated by the desired performance of the learner, but also increased assessment of individual learner requirements. Wittrock, in an article detailing the impact of cognitive psychology on instruction, touches many of the areas of cognitive functioning which can distinguish individuals.[13] Among these are cognitive style, which is the stable manner in which individuals perceive, code and store information; and cognitive strategies, which are the unique ways in which individuals process--or organize--information or knowledge in memory.

Consideration of each of these areas of cognitive functioning leads to what some authors refer to as cognitive task analysis.[14] This is the determination of instructional content based upon which cognitive processes or operations are necessary in order to perform a given task. Cognitive task analysis differs from traditional behavioral types of task analysis in that the analysis goes beyond the logical decomposition of tasks into their component skills or knowledges. The traditional task analysis, exemplified by the use of a Gagneian-type hierarchy, would break a task such as the addition of integers into rules for addition, into concepts

such as 0 as a place holder, and into discriminations such as the identification of whole numbers. What is not made explicit in Gagne's hierarchial conception of task analysis is a model of performance[15] --the specific mental operations which entail the recognition of a whole number or the assessing of propositional knowledge underlying rule utilization.

Efforts at cognitive task analysis generally follow an information processing approach, representing task performance in terms of formal process models.[16] The information-processing approach perceives the human learner as acting upon, or processing, information or data.[17] The data, as it exists in memory, has a structure and is stored and or accessed. Incoming data enters first a short-term, or working, memory store wherein processing activities occur which cause its transfer to permanent memory or long-term storage. Likewise, data in the long-term store has to be retrieved and enter working memory before it can be acted upon. Task performance, in information-processing terms, can be described as a function of the data in working memory, of the cognitive actions which govern new data entering from the external world, of data retrieved from long-term stroage, and of the integration and synthesis performed upon all of these sets of data which result in new memory structures being established. Individual differences translate into the differential processes which govern the availablity of data to the working memory from both the external (instructional context) and the internal (mind) environment, and the differential processes governing the integration and synthesis of that data.

COPING WITH COMPLEXITY

The computer has served as a metaphor for the information-processing conception of cognitive psychology. Likewise, it is the computer which provides a reasonable technology for dealing with the instructional complexity which results from these conceptions. As we begin to understand how people differ in cognitive structure, strategies, and styles which they bring to an instructional setting, the old adage "to begin where a student is" becomes more meaningful and important. But why is dealing with individual differences on such a detailed level more important now than it was in the past? It really is not an issue of being more important now, for perceptive educators have always been concerned with individual differences. Rather, the importance comes from the combined result of knowing more about what these individual differences are and the fact that we now have a technology available for dealing with them. Additionally, we no longer have the luxuries, if in fact they were luxuries, of working from a small database of generalized and specialized knowledge for use in solving our problems, or of sufficient time to allow a leisurely approach to the finding of solutions, or of educating only a relatively small number of people skilled in those processes which might reach these solutions.

Every field of human endeavor is now faced with an information explosion. Our society depends more and more upon highly-trained and educated people. Time for carrying out the educational process becomes more limited in the face of what people need to know in order to become competent. Training and education must become more effective, and those responsible for it must pay attention to and deal with individual differences in order to maximize the efficiency of the learning process.

Meaningful approaches for dealing with individual differences will inherently involve complexity. Richard Snow has already pointed out that the early goal of ATI research, to find generalizable relationships between a particular treatment and learning outcomes, has not been fruitful:

> However, as work on aptitude-treatment interaction (ATI) has proceeded, it has become clear that interactions, both among individual difference variables and between them and instructional conditions, can be so complex as to push generalizations beyond our grasp, practically speaking.[18]

Snow continues, stating that ATI research has shown the importance of detailed description of both specific instructional situations and specific groups of people. ATI demonstrates a condition not conducive to the development of broad, generalizable theory (mass solutions to individual differences?) but rather one which necessitates instructional design as a process of formative evaluation in localized environments.

In the past, the complexity inherent in any set of learners was compensated or controlled for by traditional methods which reduced or transformed a set of individual learners to the equivalence of a single learner. This point and others is used by Robinson in contrasting "traditional" with those "modern" (individualized) methods of instruction which are based on cybernetic principles and which function within complex systems.[19] To briefly summarize Robinson's thesis, variety in a complex system (i.e., learner actions) has to be matched by an equivalent compensating, regulatory variety (i.e., teacher actions) if system equilibrium (i.e., control) is to be maintained or achieved. If system variety exceeds regulatory variety, some form of constraint has to be imposed upon the system. One form of constraint is to reduce variety by such means, for example, as ignoring individual differences in a set of learners. The other form of constraint is to reduce variety by absorbing it. It is in this latter form of constraint that technology becomes important. As Robinson states, "One major solution-area that must be seriously considered is the use of 'variety eating' information-processing technology."[19]

The computer in both of its two major instructional applications, computer-managed instruction (CMI) and computer-assisted instruction

(CAI), serves to absorb the variety associated with the learners or amplify the variety associated with the teachers. CMI is the use of the computer in its more normal function of data processing. It provides the mechanism by which individual aptitudes can be assessed, and prescribed instructional alternatives can be assigned in accordance with the assessed aptitudes. CMI also fulfills the need for collecting learner data as part of the formative evaluation process Snow talks about in the determination of useful ATI's. CMI deals with absorbing the variety which exists between learners.

CAI is the use of the computer to instruct a learner "one-on-one." Its key aspects are interaction and the capability for exercising intelligent-appearing judgment. Where CMI deals with inter-learner variability, CAI deals with intra-learner variability. In the same manner that product-forms of programmed instruction preceded the conception of PI as process, CAI--as the product-form of computer-based instruction (CBI)--has generally preceded the more management-and-design, process-orientation of CMI.

As with programmed instruction, much of the nature of the CBI technology can be revealed by looking at its product form. Initial attempts at CAI clearly show its evolutionary basis in PI. These early CAI attempts, and for that matter, much existing CAI, utilize lessons which are characterized by the linear presentation of "frames" of information followed by a response mode. This has lead to the often-heard criticism of "page turning activity" which, it is claimed, does not justify the greater cost of the computer technology in relation to the use of such media as programmed texts or automated sound/slide presentations. The true difference between PI and CBI as instructional technologies lies in CBI's potential ability to deal with the unexpected and the unplanned.

Returning to Robinson's discussion of the cybernetic aspects of classroom control, it is important to emphasize his contention that only variety can control or compensate for variety. In cybernetics, this is known as "The Law of Requisite Variety." In instructional terms, it represents the ability to provide flexible alternative paths of informational access in order to offset differences in cognitive structure, strategies, and styles. Programmed instruction, through self-pacing, offers one level of flexibility through the manipulation of the time variable. However, having more time available may not be sufficient if the specific instructional approach taken has requisites which are not within the cognitive capabilities of the individual.

Branching programmed instruction exemplified by Crowder's intrinsic programming can be anticipated not to be sufficient, either, when the full range of potential cognitive attributes are considered. Though much CAI written in the past and being written today is characterized by a "printed frame" format with brancing between frames, this is probably a transitional state of affairs, existing until the evolution of programmed instruction to computer-based instruction is complete. The full impact of the computer upon programmed instruction will probably lie beyond the planned interaction of today's structured lessons. Instead, it may lie in the use of the computer as a patient partner in dialogues or conversations on an instructional topic. If we are novices, the computer can act more as the mentor, guiding us with leading statements and questions. If we have more experiences and cognitive comprehension of a topic area, the computer can serve as a knowledgeabel colleague, allowing us to explore different avenues of "his" experience.

The conversational approach to instruction via the computer has already been suggested by Pask.[20] Pask has formulated a "conversational theory" for the learning of complex subject-matter. The result of this theoretical position has been the development of computer-based systems which represent the understanding of a subject-matter by both the teacher and the learner. This system, in turn, can be used to instruct the student in the subject-matter. The teacher mode is one of "directing attention to what needs to be done" while the learner mode is one of "assimilating the subject matter."

To simplify greatly Pask's approach, a subject-matter expert articulates a subject-matter as a collection of "TOPICS." A TOPIC represents a set of formal propositional relationships in a particular context. The CONCEPT of a TOPIC is the mental representation (cognitive structure) which satisfies the accepted and formal relationships which the TOPIC consists of. The understanding of a learner is the ability to construct or reconstruct the CONCEPT of a TOPIC. It is possible for the "teacher" and the "learner" to have different CONCEPTS of a TOPIC, but if each CONCEPT leads to an equivalent outcome or satisfies the same relationship, then they are both acceptable or in agreement. The subject-matter becomes a formal network of TOPICS known as an "entailment structure." This entailment structure is externalized via a computer representation and becomes available to both teacher and learner. The understanding of a subject-matter entails a conversation between the teacher and the learner about the TOPICS in the entailment structure, and understanding is exhibited when there is agreement between the teacher and the learner about the CONCEPT of a TOPIC which a learner has expressed.

In Pask's early work, the computer served to model the entailment structure and the conversation was between a live teacher and student. Later Pask suggested that the computer itself take on the teaching function:[21]

> Under these conditions the computer is able to direct the student to appropriate information and demonstrations...The student can carry out tests of his understanding and the computer will check which of the derivations are correct...[22]

As such, the computer models the subject-matter and the learner converses with the computer about that subject-matter. Unlike prestructured "branching" of PI or existing CAI, the exact nature of the conversation for a particular student is unknown beforehand. However, both the computer and the learner interact on the basis of the specific model of the subject-matter. Thus, the variety of computer-response capabilities tends to match the variety of learner inquiries.

Intelligent CAI is a term which recently has come to refer to the more sophisticated level of interaction suggested by Pask's formulations. An example of intelligent CAI is work done by John Seely Brown and his colleagues with SOPHIE (SOPHisticated Instructional Environment).[23] SOPHIE was originally designed to simulate electronic circuitry through computer programs. Thus, SOPHIE would have a model of a particular circuit and "knowledge" of its operation. With this model and a natural language interpreter based upon artificial intelligence research, SOPHIE enabled a student to make inquiries concerning the operation of the circuit based upon stated settings of specific input conditions. In the research Brown did, SOPHIE was used to model an electronic power supply for the purpose of supporting training in troubleshooting procedures. At the beginning of the program, SOPHIE would initialize a fault condition, followed by statements of initial control settings of the device. Following are a few examples of the possible interchange between the computer and the learner:

Learner: What is the output?
Computer: The output voltage is 1.2 volts.
Learner: Is that right?
Computer: In a working circuit, the output voltage is 30.1 volts. That value is incorrect.
Learner: What is the voltage between the current-limiting transistor...and the constant-current source?
Computer: The voltage at N4 is 2.8 volts.

As you can see, the learner is able to freely "converse" with SOPHIE, moving the instructional interaction beyond the preplanned and limited options of frame-oriented instruction.

When Pask and Brown were doing their initial research, available computer technology necessitated large and complex hardware configurations. However, as the closing years of the seventies have shown, dramatic increases in computer-power, matched by equally dramatic declines in both size and cost, make it entirely feasible in the immediate future for conversation-like instruction to be supported by computer-based instructional technology. It will be through such technology that instructional designers and technologists will be able to begin to apply the knowledge accumulating from the cognitive sciences in order to meet the diverse instructional needs of individual learners. With the evolution of instructional technology from programmed instruction into computer-based instruction, we are coming very near to fully realizing the oroginal purpose Pressey conceived for his teaching machine--to free the learner from the limitations of time and place.

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